such cases, with the first to eleventh invention alloys, the alloys with a low content of copper in particular are rather low in the content of the gamma phase and contain beta phase. In a heat treatment, the beta phase changes into gamma phase, and the gamma phase is finely dispersed and precipitated, whereby the machinability is improved.

[0048] But a heat treatment temperature at less than 400°C is not economical and practical in any case, because the aforesaid phase change will proceed slowly and much time will be needed. At temperatures over 600°C, on the other hand, the kappa phase will grow or the beta phase will appear, bringing about no improvement in machinability. From the practical viewpoint, therefore, it is desired to perform the heat treatment for 30 minutes to 5 hours at 400 to 600°C.

BRIEF DESCRIPTION OF THE DRAWING

[0049] Fig. 1 shows perspective views of cuttings formed in cutting a round bar of copper alloy by lathe.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Example 1

[0050] As the first series of examples of the present invention, cylindrical ingots with compositions given in Tables 1 to 15, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to produce the following test pieces: first invention alloys Nos. 1001 to 1007, second invention alloys Nos. 2001 to 2006, third invention alloys Nos. 3003 to 3009, fourth invention alloys Nos. 4002 to 4020, fifth invention alloys Nos. 5003 to 5016, sixth invention alloys Nos. 6009 to 6015, seventh invention alloys Nos. 7018 to 7029, eight invention alloys Nos. 8001 to 8008, ninth invention alloys Nos. 9001 to 9006, tenth invention alloys Nos. 10001 to 10008, and eleventh invention alloys Nos. 11001 to 11011. Also, cylindrical ingots

with the compositions given in Table 16, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to produce the following test pieces: twelfth invention alloys Nos. 12001 to 12004. That is, No. 12001 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as first invention alloy No. 1006 for 30 minutes at 580°C. No. 12002 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as No. 1006 for two hours at 450°C. No. 12003 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as first invention alloy No. 1007 under the same conditions as for No. 12001 - for 30 minutes at 580°C. No. 12004 is an alloy test piece obtained by heat-treating an extruded test piece with the same composition as No. 1007 under the same conditions as for No. 12002 - for two hours at 450°C.

[0051] As comparative examples from the prior art, cylindrical ingots with the compositions as shown in Table 17, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to obtain the following round extruded test pieces: Nos. 13001 to 13006 (hereinafter referred to as the "conventional alloys"). No. 13001 corresponds to the alloy "JIS C 3604," No. 13002 to the alloy "CDA C 36000," No. 13003 to the alloy "JIS C 3771," and No. 13004 to the alloy "CDA C 69800." No. 13005 corresponds to the alloy "JIS C 6191." This aluminum bronze is the most excellent of the expanded copper alloys under the JIS designations with regard to strength and wear resistance. No. 13006 corresponds to the navel brass alloy "JIS C 4622" and is the most excellent of the expanded copper alloys under the JIS designations with regard to corrosion resistance.

[0052] To study the machinability of the first to twelfth invention alloys in comparison with the conventional alloys, cutting tests were carried out. In

the test, evaluations were made on the basis of cutting force, condition of chippings, and cut surface condition. The tests were conducted in this manner: The extruded test pieces thus obtained were cut on the circumferential surface by a lathe provided with a point noise straight tool at a rake angle of -8 degrees and at a cutting rate of 50 meters/minute, a cutting depth of 1.5 mm, and a feed of 0.11 mm/rev. Signals from a three-component dynamometer mounted on the tool were converted into electric voltage signals and recorded on a recorder. The signals were then converted into the cutting resistance. It is noted that while, to be perfectly exact, the amount of the cutting resistance should be judged by three component forces - cutting force, feed force, and thrust force, the judgement was made on the basis of the cutting force (N) of the three component forces in the present example. The results are shown in Table 18 to Table 33.

[0053] Furthermore, the chips from the cutting work were examined and classified into four forms (A) to (D) as shown in Fig. 1. The results are enumerated in Table 18 to Table 33. In this regard, the chippings in the form of a spiral with three or more windings as (D) in Fig. 1 are difficult to process, that is, recover or recycle, and could cause trouble in cutting work as, for example, getting tangled with the tool and damaging the cut metal surface. Chippings in the form of a spiral arc from one with a half winding to one with two windings as shown in (C) in Fig. 1 do not cause such serous trouble as chippings in the form of a spiral with three or more windings, yet are not easy to remove and could get tangled with the tool or damage the cut metal surface. In contrast, chippings in the form of a fine needle as (A) in Fig. 1 or in the form of arc shaped pieces as (B) in Fig. 1 will not present such problems as mentioned above, are not as bulky as the chippings in (C) and (D), and are easy to process. But fine chipping as (A) still could creep in on the slide table of a machine tool such as a lathe and cause mechanical trouble, or could be dangerous